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EVALUATION OF HEAD AND FACE INJURY POTENTIAL OF CURRENT AIRLINE SEATS DURING CRASH DECELERATIONS

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EVALUATION OF HEAD AND FACE INJURY POTENTIAL OF CURRENT AIRLINE SEATS DURING CRASH DECELERATION

I. Introduction.

A large percentage of deaths in commercial-airline crashes is produced as the body and lower limbs flail around the seat belt. According to a previous study,[1] a 10-foot-diameter sphere of clear area would be necessary to prevent a person from striking some portion of his body against surrounding structures. This study is concerned primarily with head impacts that may occur against most portions of the seats. Thirty-five impact studies were made with an instrumented dummy head against various portions of eight different makes of airline seats to determine the "g" time-force parameters of metal deformation and seat break-over.

II. Discussion.

Figure 1 reproduces summary data[2] showing the tolerances of the human face and head to

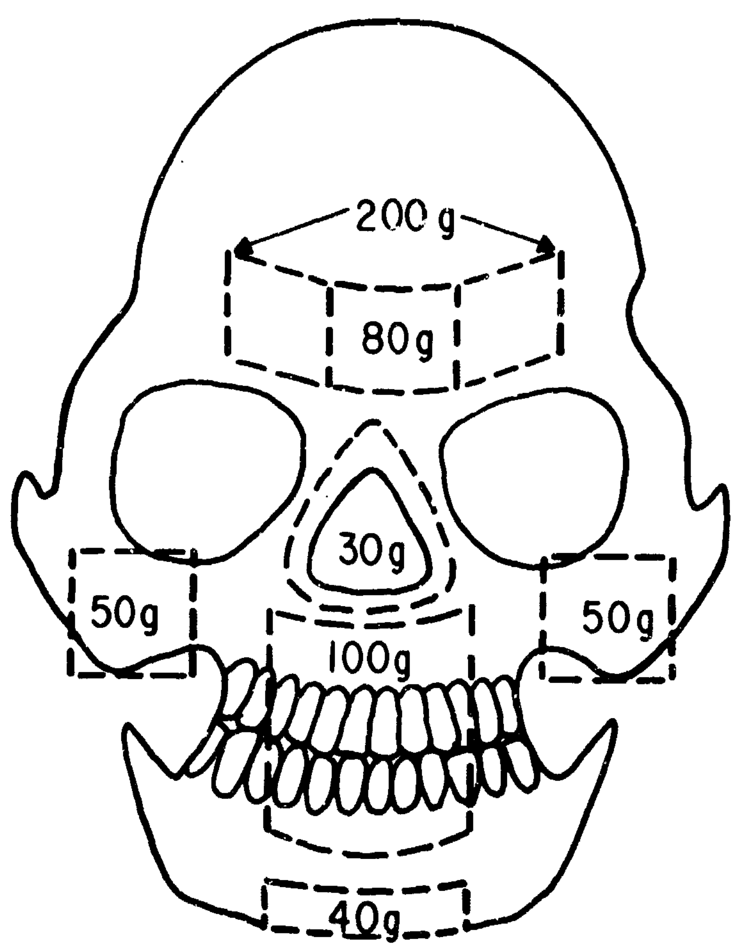


FIGURE 1. Summary of maximum tolerable impact forces on a padded deformable surface.

TABLE 1. Summary of estimated injury potential of airline seats in head impact.

(L=lethal F=fractures U=unconscious S=safe)

Seat	Test No.	Forehead		Zygomatic		Nose		Teeth		Mandible	
A	1	S	U	F	U	F	U	S	U	F	U
	2	F	L	F		F		F		F	
	3	F	L	F		F		F		F	
	4	S		S	U	F	U	F	U	F	U
	5	S		S	U	F	U	F	U	F	U
	7	S	U	F	U	F	U	F	U	F	U
	8	F	U	F	U	F	U	F	U	F	U
	17	S	U	F	U	F	U	F	U	F	U
B	6	F	L	F		F		F		F	
C	10	S		F	U	F	U	S	U	F	U
	11	S	U	F	U	F	U	F	U	F	U
	13	S		S	U	F	U	S	U	F	U
D	9	F	U	F	U	F	U	F	U	F	U
E	18	S		S	U	S	U	S	U	S	U
	19	S		S	U	F	U	F	U	F	U
	20	S		F	U	F	U	F	U	F	U
	21	F	L	F		F		F	U	F	
F	22	F	L	F		F		F		F	
	23	F	L	F		F		F		F	
	24	F	L	F		F		F		F	
	25	F	L	F		F		F		F	
G	26	S		S		F		S		S	
	27	S		S		S		S		S	
	28	S	U	F	U	F	U	F	U	F	U
	29	F	U	F	U	F	U	F	U	F	U
	30	F	L	F		F		F			
H	31	F	L	F		F		F			
	32	F	U	F		F		F		F	
	34	F	U	F		F		F		F	

resist fracture during impact against *deformable structures*.

Impact velocities for all tests were held constant at 30 ft/sec in order to compare the forces required to deform various portions of the seats. This is about 10 to 15 ft/sec less than may be expected in severe but survivable crashes.[3]

Table 1 summarizes the author's evaluation of injury and state of consciousness for each impact as applied to different parts of the face and head. In airline crashes it is important for the passengers to remain conscious so that they can escape rather than be asphyxiated or burned to death even though otherwise uninjured.

Five impacts of the dummy head were made against Seat A at the points shown in Figure A1 (Figures A1 through A10 are in the Appendix.) by numbers 1, 2, 3, 7, and 8. Corresponding "g" time-force curves are presented. Impact #1 (on the top of the middle seat) produced a sizeable deformation in the soft metal structure. The metal deformed readily and *contoured* to the head, distributing the force over a large area of the skull. The peak force was about 70g with a slow rise time (20 milliseconds). The deceleration extended over 40 milliseconds. Referring to Figure 1, we would expect this impact to produce no bony injury if struck by the forehead or teeth-maxilla areas, but it would be of sufficient force to fracture a single zygomatic (cheek bone), nose, or mandible (jaw bone). In all five instances, however, the passenger would be rendered unconscious.[2]

Impact #2 was between the left and middle seats with the seats in the upright position. Most of the force (120g peak) was used in forcing the seat backs to break forward. There was little deformation of the seat structure, causing the impact loads to be concentrated on a small area of the head. This would have produced fatal fractures. It is of interest that a steady pull of only 10 to 12 pounds is needed to force one of these seat backs forward.

Impact #3 against the center of the serving tray in the left seat back (with the seat upright) produced two peaks of over 100g: one when the seat back was forced forward and the other when the head subsequently struck the lower cross member of the seat back. There was no deformation of the serving tray. Estimates of injury potential presented in Table 1 are based on a previous report [2] and the area of contact of structure with the head. For injury estimates for the following figures, refer to Table 1.

Some seat-design engineers feel that under actual crash conditions the "break-away" type of seat back will fold forward from its own momentum out of the way of the head. If this is true, the head possibly will strike the lower portion of the seat back or a tubular cross member. Impact #7 simulates this condition. The right seat back was impacted in the forward position. In the graph for #7, the first small peak of about 15g was produced in bending the thin metal at the bottom of the seat before the head made contact with the heavy tubular cross member concealed beneath it. At that time a very lethal, long-duration (20 milliseconds) force of over 100g was applied to the head.

Impact #8 was against the top of the right seat back (seat upright) at the top edge of the serving tray. Note similarity of curves 3 and 8.

Since the arms supporting the folding serving trays have broken off in some airline crashes and caused serious injury, two impacts were made on the unfolded trays of Seat A (Figure A2). Impact #4 was centered in an area between the left and center trays, whereas impact #5 was against the right edge of the left seat tray. The tray support arms in both cases bent several inches but did not fracture. The impacts produced long duration forces of about 40g or less.

In Figure A3, the dent left by the head impact against the top tubular structure (Seat B) is barely visible in the photograph. The sharp rising 120g peak force applied to an area of not more than 1 sq in. of the head would undoubtedly have caused fatal injuries.

Impact #9 against the top edge of Seat C produced a somewhat larger dent (Figure A4). The g-force curve looks almost as severe as the one in Figure A3; however, there is one important difference. Since the metal did deform and contour to the curvatures of the head, the pressure in pounds per square inch on the head would be much less than in the previous figure and the danger of injuries reduced accordingly.

Three impacts against Seat D in Figure A5 show that it is a fairly safe seat for head impact. The top edge of the left seat back (test #10) deformed 11 inches and contoured perfectly to the head. Note that initial bending of the structure started at 20g and that the force is spread out with a slow rise time and a peak of not over 60g. Test #13 against the top rear surface of the right seat back shows a more desirable pattern. The head did not experience over 40g; however, test #11 against the tubular cross member at the bottom of the right seat back produced peak forces in excess of 80g. Throughout this report this type of tubular structure is shown to be very dangerous and undoubtedly causes a large number of head and leg fractures. This area of the seat requires additional safety-design consideration.

Seat E in Figure A6 (mostly fabricated of sheet aluminum) is shown by the force curves to have very good deforming characteristics with the exception of the lower tubular cross member, which produced fatal impact forces of 180g.

Seat F (Figure A7) is constructed of aluminum tubes and produced high forces during all impacts. The most dangerous part of the seat, however, is the aft end of the rigid seat arm protruding rearward between the seat backs. Test #24 against one of these arms produced a peak force of 250g.

Seat G (Figure A8), similar in construction to that shown in Figure A4, produced low g-forces on the upper structure but again pointed out the danger of the rigid arm (test #30—180g).

Seat H has two heavy, square-edged, tubular structures in the lower portion of the seat back. Tests #31 (Figure A9) and #32 (Figure A10) show unusually high g-forces when these rigid structures are impacted. The top of the seat back is also of square tubular construction and

produced 140g when impacted (#34, Figure A10).

III. Conclusions.

Impact tests against the eight airline seats studied show that portions of some have good deforming characteristics. The most lethal design features were found to be tubular construction (round or square), nondeforming serving trays, rigid seat arms protruding rearward between the seats, and excessive break-over forces. An analysis of this series of head impacts based on earlier work[2] shows that 30% would have been fatal, 80% would have produced facial fractures, 97% would have rendered the passengers unconscious, and only 3% would have produced no injuries or unconsciousness.

This study shows that the following design requirements are necessary to improve the crash-safety design of seats:

a. Tubular construction should only be used in areas where it cannot cause injury.

b. Serving trays and seat backs should be molded of light aluminum sheet or other material that will deform at loads less than 30g and *contour* itself to the head and face.

c. All exposed areas should be padded with sufficient slow-return foam to aid distribution of the impact force over the contour of the face.

d. The forces necessary to break the seat back forward should be reduced.

e. The lethal characteristics of seat arms should be eliminated.

REFERENCES

1. SWEARINGEN, J. J., HASBROOK, A. H., SNYDER, R. G., and MCFADDEN, E. B.: Kinematic Behavior of The Human Body During Deceleration. CARI Report 62-13, FAA, Oklahoma City, Okla., June 1962.
2. SWEARINGEN, J. J.: Tolerances of The Human Face to Crash Impact. OAM Report AM 65-20, FAA, Oklahoma City, Okla., July 1965.
3. Studies of high speed movies taken of dummy flailing in the 1964 FAA-AvSER crash test of a DC-7 aircraft.

APPENDIX

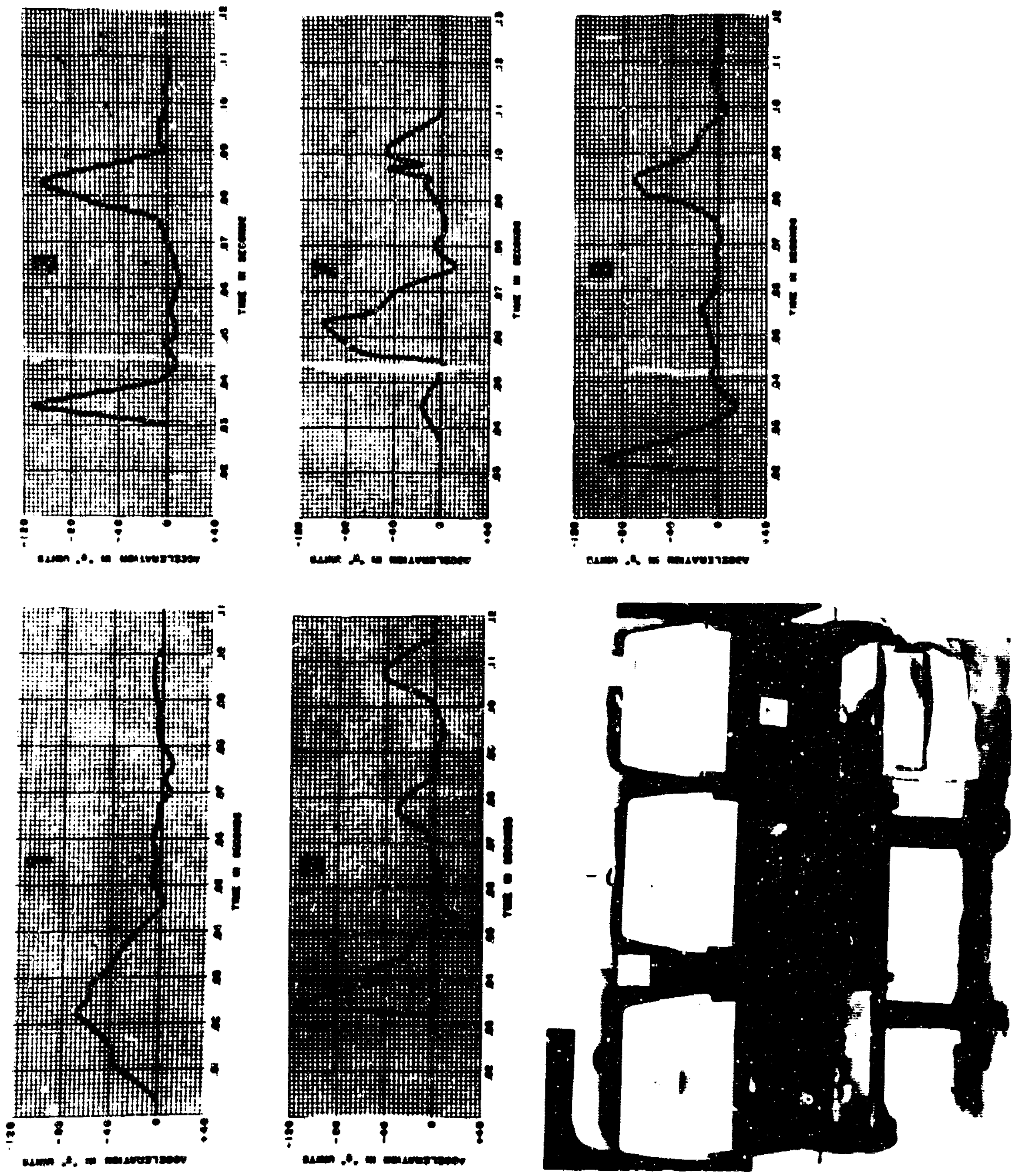


FIGURE A1. Seat A.

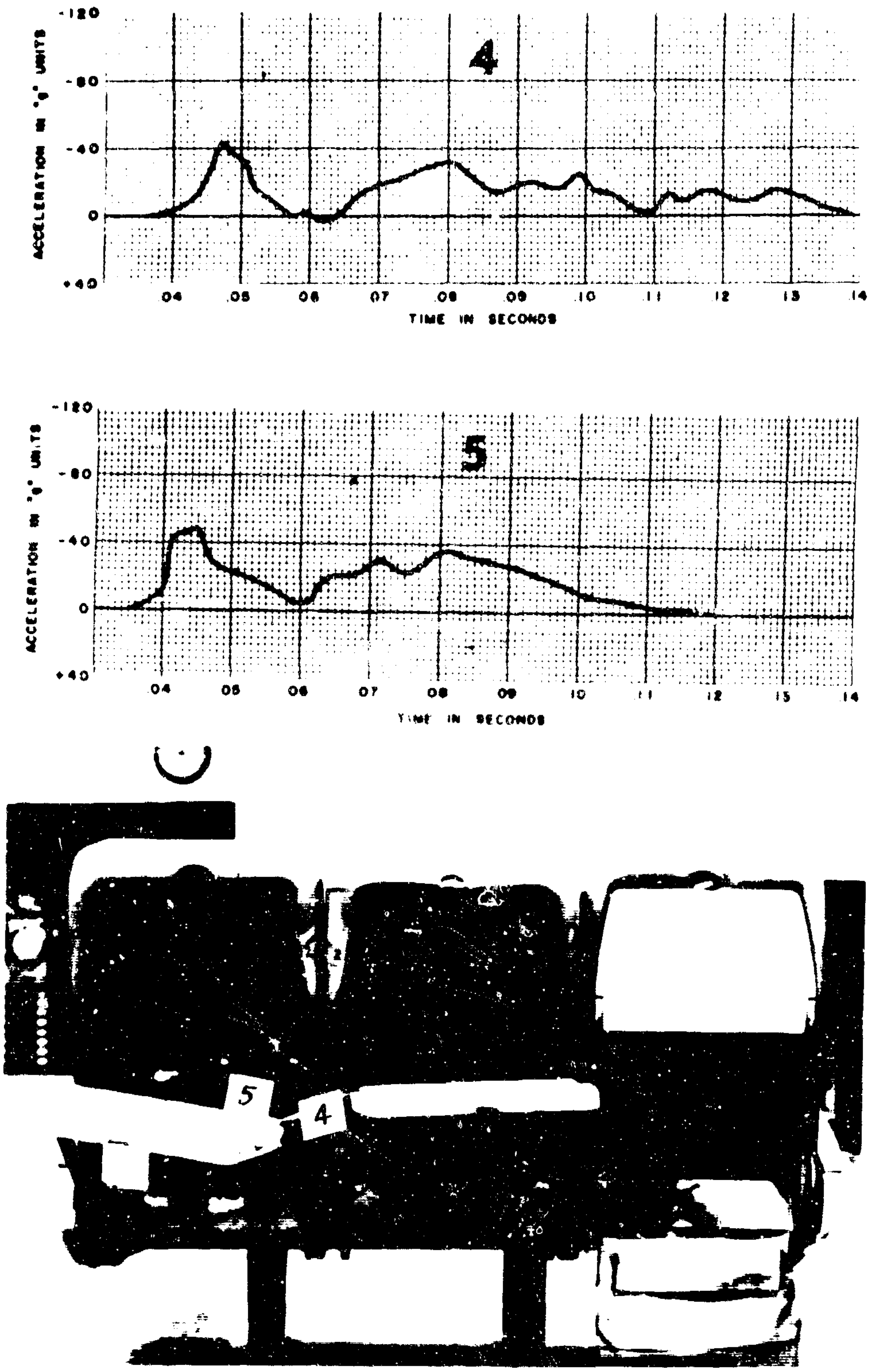


Figure A2. Seat A.

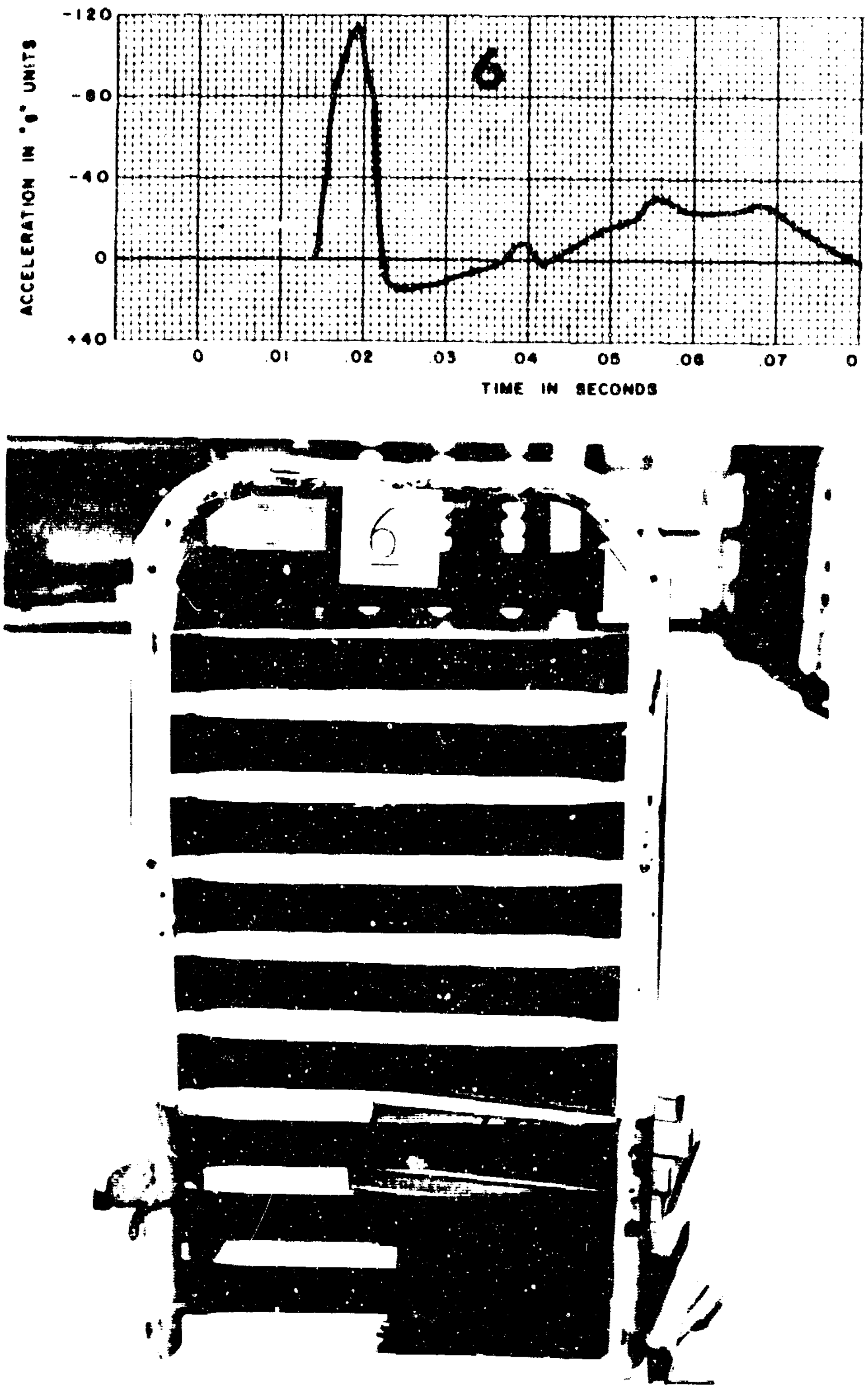


FIGURE A3. Seat B.

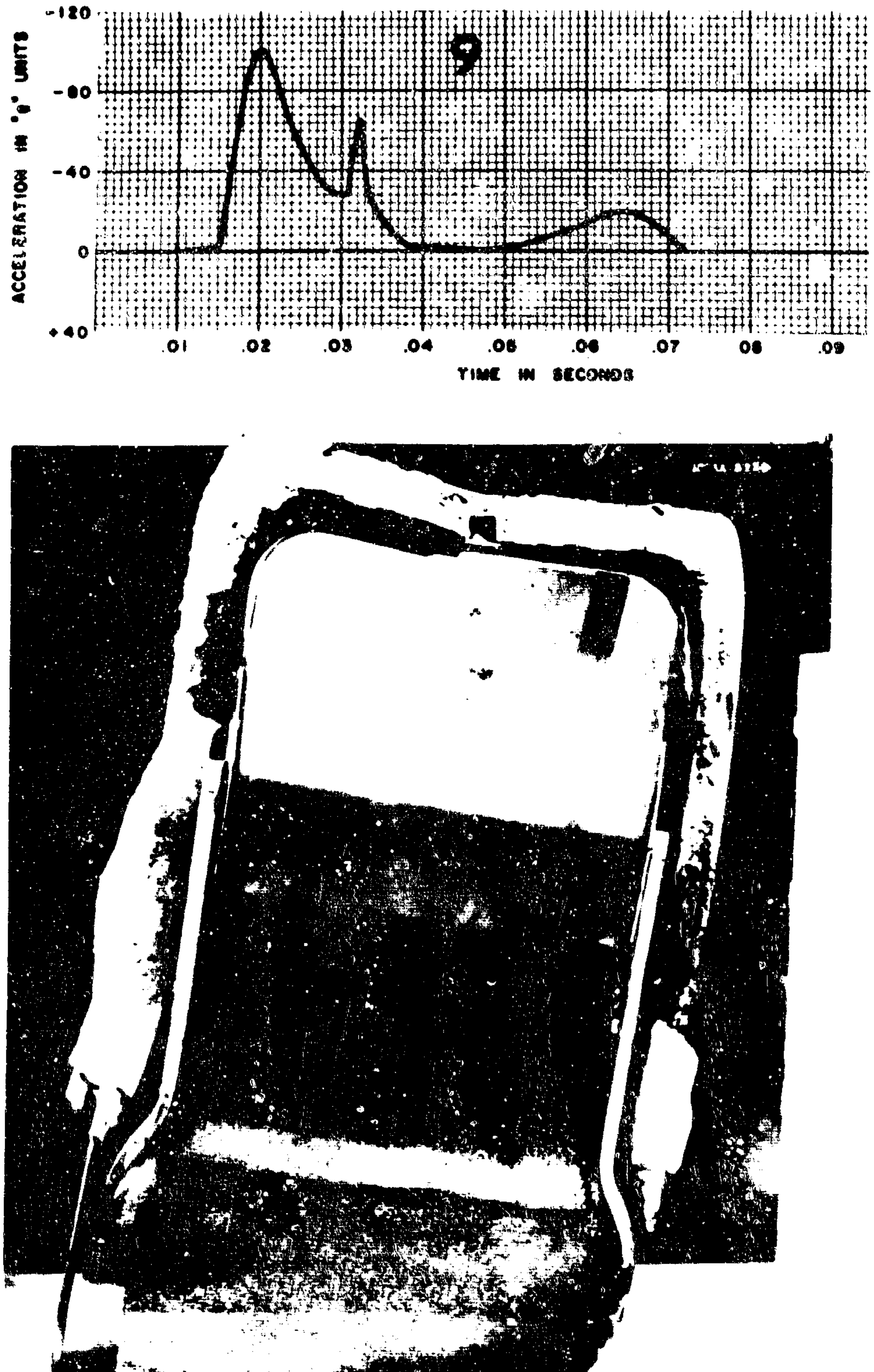


FIGURE A1. Seat C

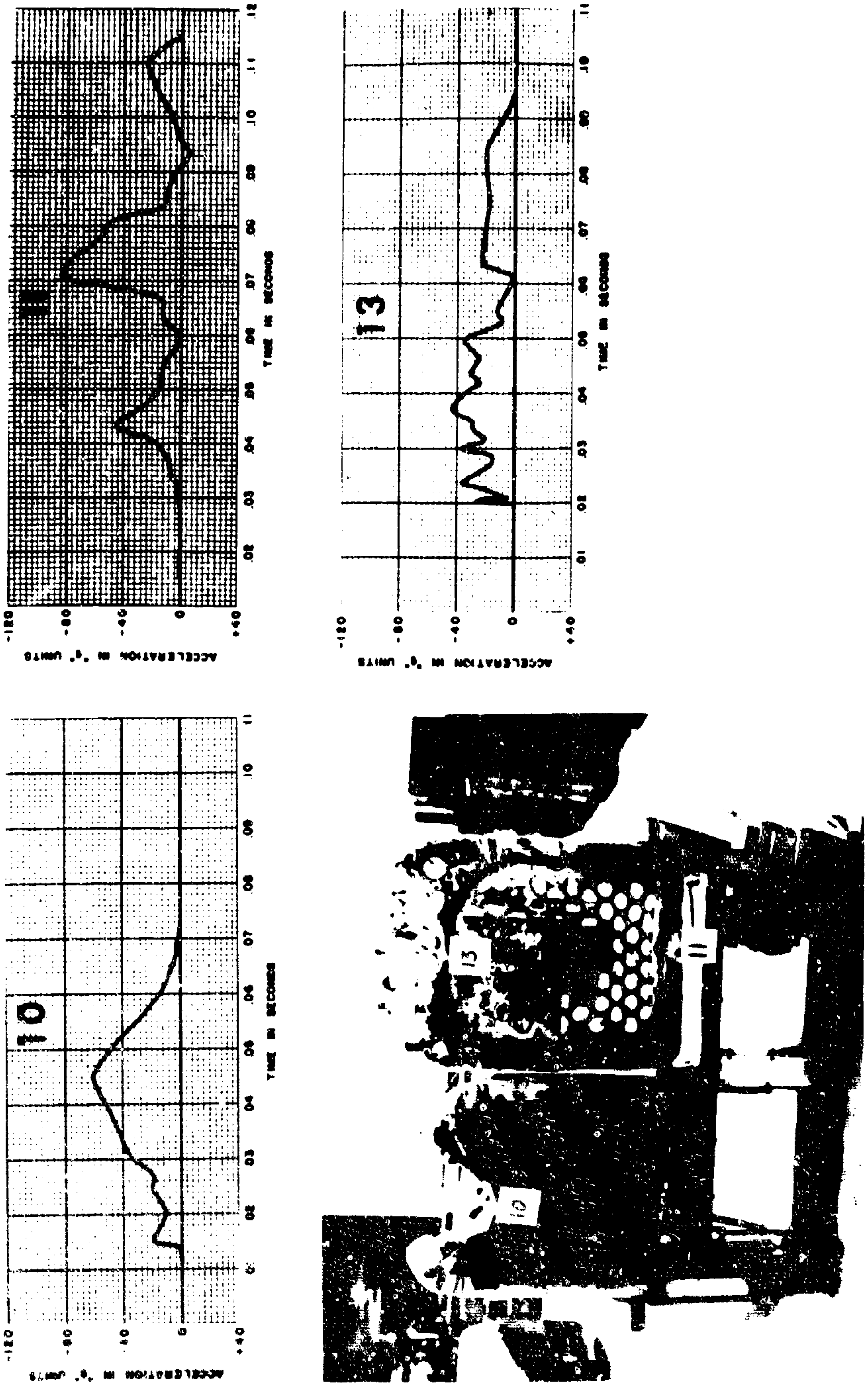


FIGURE A5. Seat D.

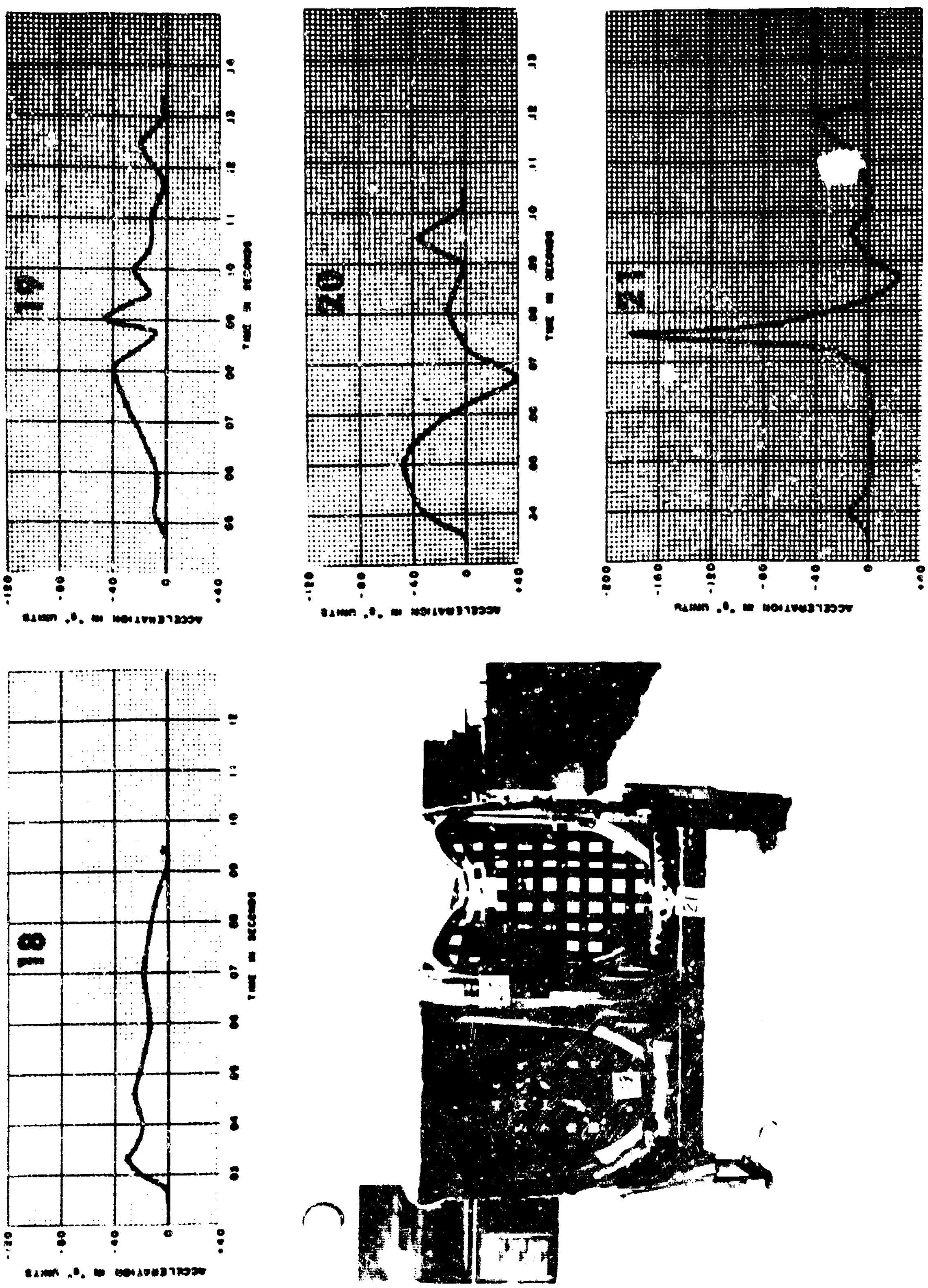


FIGURE A6. Seat E.

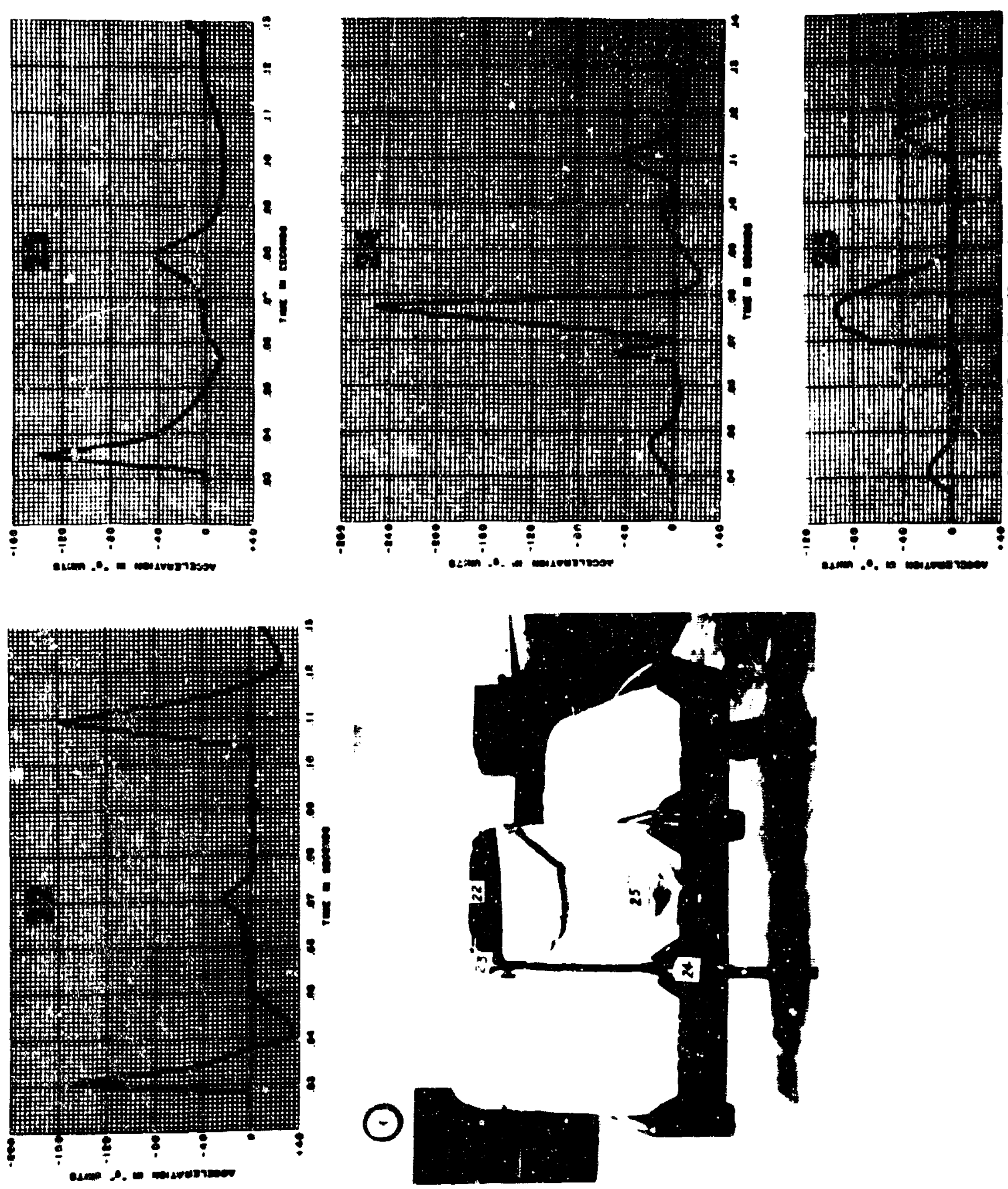


FIGURE A7. Seat F.

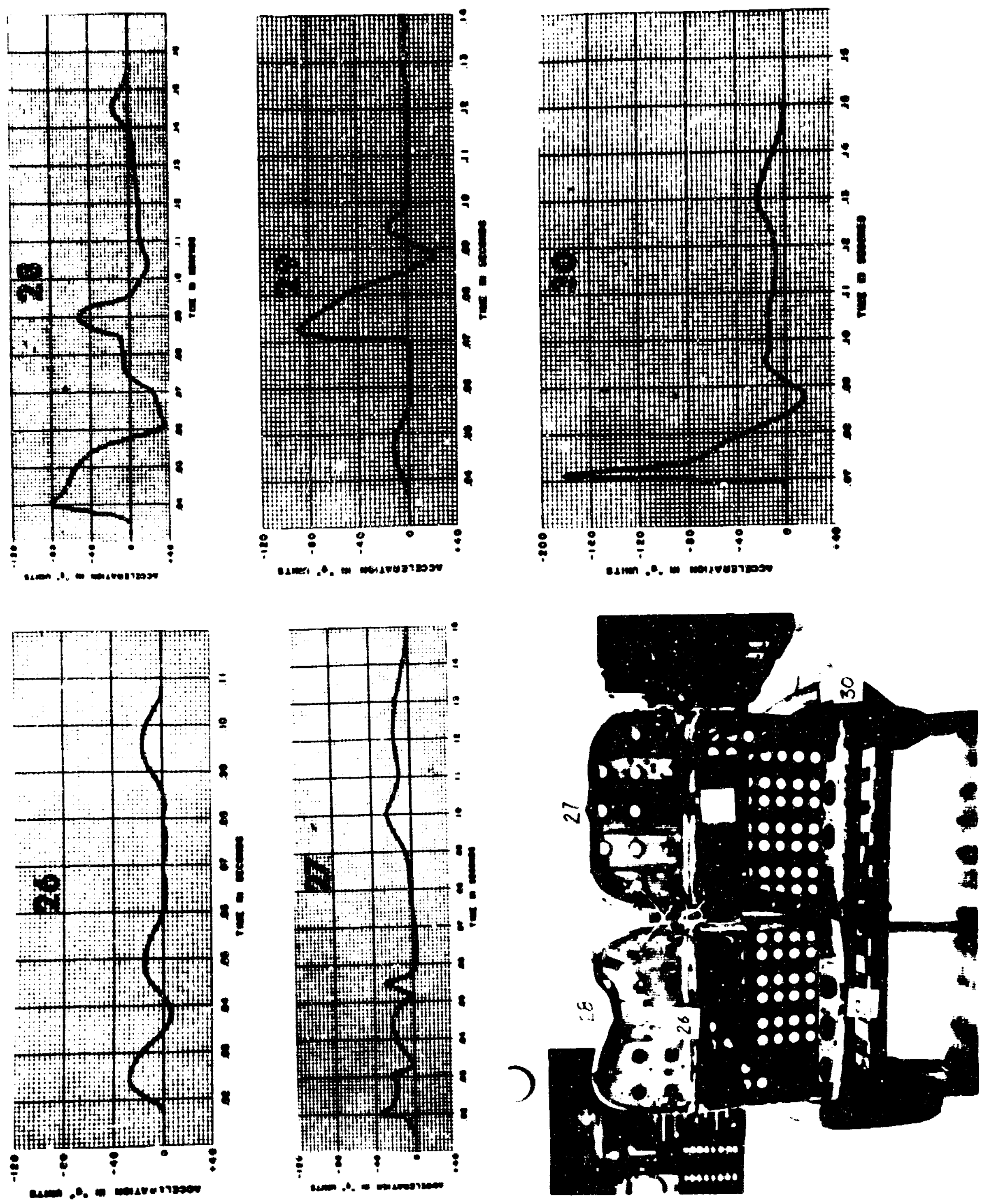


FIGURE A8. Seat G.

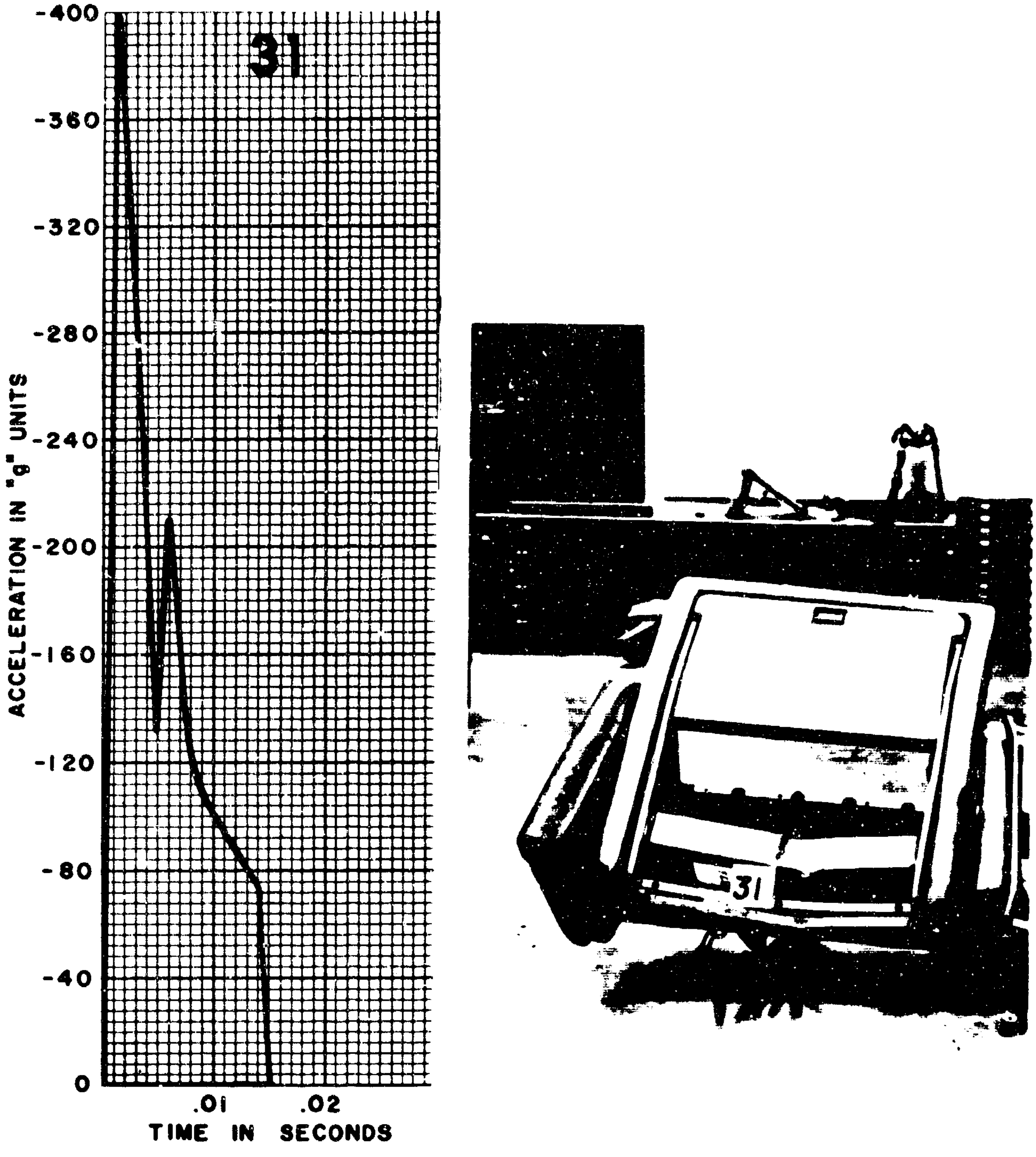
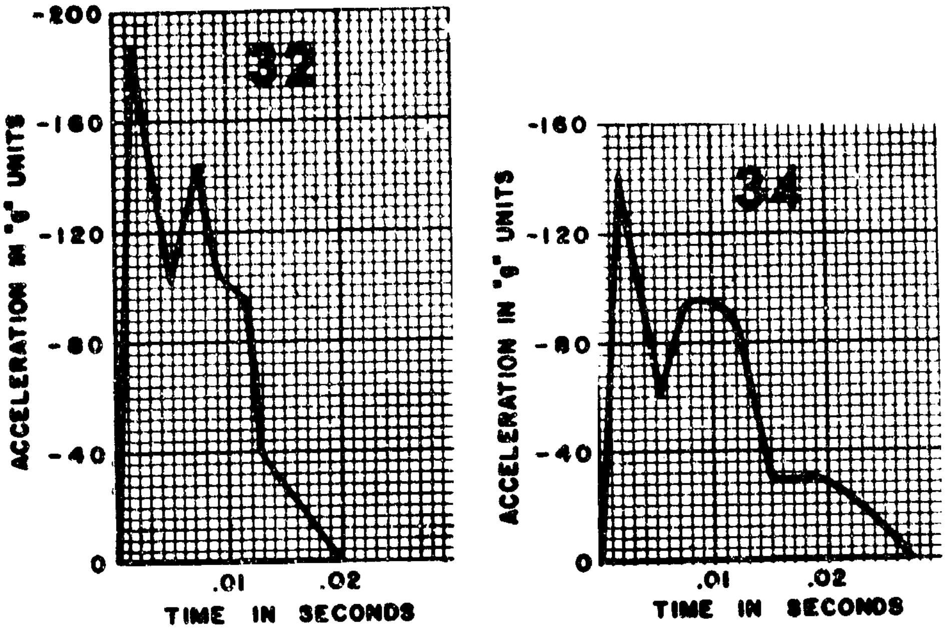


FIGURE A9. Seat H.



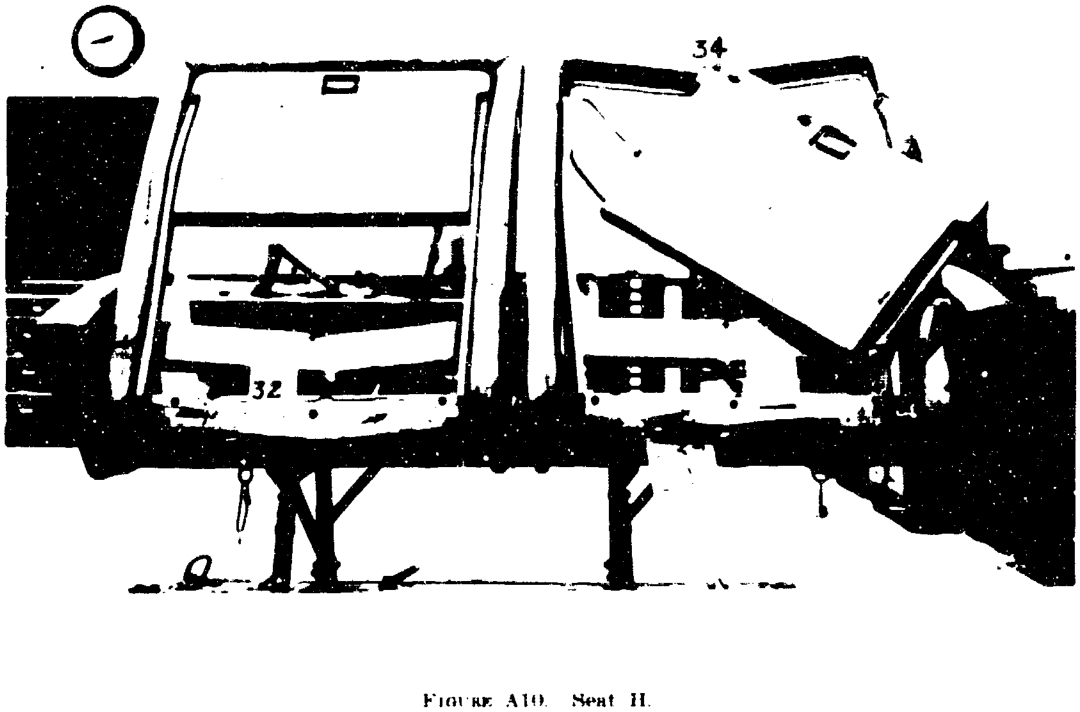


FIGURE A10. Seat H.